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Research Article
Effects of Varied Levels of Amino Acid-Rich Sweet Potato Composite on the Reproductive Performance of Rabbit Does Reared in the Tropics

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Abstract
Objective: The primary objective of this study was to investigate how varied levels of Amino Acid-rich Composite Sweet potato affected lactating performance and overall Reproductive Cycle Outcomes in does. **Materials and Methods:** The crude protein content and amino acid profile of leaf, roots and composite meal produced from 65% root and 35% leaves for two varieties of sweet potato (*Ipomoea batatas* Lam.) namely, TIS 87/0087 white flesh sweet potato (WFSP) and CIP 440293 orange flesh sweet potato (OFSP), were analyzed. Twenty-five rabbit does of mixed breeds (New Zealand White×California×Chinchilla) aged 6-7 months were assigned randomly to one of five experimental diets: T1 (control), T2 and T3 contained 25 and 50% orange-fleshed CSPM and T4 and T5 contained 25 and 50% white-fleshed CSPM. The diets comprised 10.6-12.6% crude fibre, 16.4-17.6% crude protein and metabolizable energy of 2610-2788 kcal kg^{-1}. **Results:** The crude protein content in roots of 87/0087 (WFSP) and CIP 440293 (OFSP) were 3.32 and 8.04%, respectively. There was an appreciable higher value of crude protein in the leaf of TIS 87/0087 (11.18%) and CIP 440293 (11.26%), respectively. The crude protein content was least in composite WFSP (6.13%) and higher in composite OFSP (14.8 %). Total amino acid content ranged from 7.704 to 18.35 and 23.717 to 23.863 g/100 g protein for root and leaf samples, respectively. The overall feed intake of does in all the treatments was not significantly different (p>0.05). Does fed on diets T4 and T5 had the largest litter size at birth (5.00) compared to the other treatments. In different treatments, there was no significant difference in initial average body weight, gestation duration, or litter weight of does at birth. **Conclusion:** The high content of crude protein and its quality amino acids in the two varieties of the sweet potato composite meals placed it on a commensurate level for consideration as a potential replacement for expensive conventional protein source in livestock diet.

Key words: Amino-acid, sweet potato, rabbit feeding, milk yield, reproductive performance

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Nutrition is one of the factors that could influence reproductive performance by limiting productivity especially during pregnancy and lactation[1]. An understanding of nitrogen nutrition, especially protein and amino acid needs, is therefore critical for developing productive and cost-effective domestic animal diets.

The evaluation of the protein value of a feedstuff in terms of nitrogen and amino acid availability is the first step in formulating balanced meals with a lower crude protein content.

Growing rabbits require diets that contain certain proportions of 10 of the 21 amino acids that make up proteins[2]. With two extra amino acids that can partially replace two of the necessary amino acids, they are known as the basic or essential amino acids. The list include: Arginine, histidine, leucine, isoleucine, lysine, phenylalanine plus tyrosine, methionine plus cystine, threonine, tryptophan and valine arginine, histidine, leucine, isoleucine, lysine[2]. The nutrition of rabbit in Nigeria is primarily based on forage whose growth and availability in the dry season cannot sustain all-year rabbit production[3] and had mitigated the potential increase in rabbit production.

More importantly the reproductive phase of rabbits is around 45 percent of the entire life. As a result, factors impacting doe performance during lactation will affect kit development and survival before and after weaning, as well as meat yield and profit on commercial farms. Aside from environmental variables like high temperatures, poor feed component quality can affect rabbit and other species' productivity and reproduction. Maertens *et al.*[4] found that rabbit kits primarily rely on mothers' milk up to 21 days for survival and growth.

The conflicting requirements of gestation and lactation have a deleterious impact on milk output and composition, as well as body condition, reproductive traits and milk supply[5]. Dietary needs of the reproductive doe on the other hand, are diametrically opposite, since they require a lot of energy to stimulate lactation and a lot of fibre for digestive health[6].

Olaleru *et al.*[7] reported that composite sweet potato can support the growth performance of kids of rabbit doe without adverse effect on the reproductive performance of rabbits.

Read *et al.*[8] reported that from a few days before kindling until 25 days postpartum, a diet high in quality protein and energy is required to meet the high nutritional needs during this time, followed by a diet high in fibre until weaning to protect kits from digestive problems after weaning. However, in terms of litter health, this strategy is ineffective in meeting the demands of pregnant and lactating does at the same time[9], leading the does to lose body condition. As a result, introducing a feed component that may provide high fibre and protein without compromising the energy level required to fulfil the rabbit's physiological condition could improve doe and kit performance.

The sweet potato plant has a high energy content and can potentially replace the conventional maize in rabbit diet[10]. The sweet potato roots have a higher protein content when compared to the root crops[11]. Sweet potato leaves are high in critical amino acids like lysine and tryptophan, which are constantly short in grains. As a result, sweet potato may easily substitute grain-based animal diets[12]. There are lots of information on the usage of sweet potato plant but there is limited information on the use of the composite sweet potato meal on the reproductive performance of rabbits. Therefore, this study was conducted to evaluate the amino acid profiles and protein quality of composite sweet potato meal from two varieties as well as the reproductive performance of does raise on diets containing the composite sweet potato.

MATERIALS AND METHODS

Animals and experimental design: The experiment was conducted at the University of Ibadan's Rabbitry Unit, Teaching and Research Farm, in Ibadan, Oyo State, Nigeria. A total of twenty-five does comprising of mixed breeds (New Zealand White×California×Chinchilla) were used for this experiment.

The does aged 6-7 months were allocated randomly into five treatments each treatment having five does. The animals were caged individually. Throughout the duration of the experiment water and feed were offered *ad libitum*. Each doe was housed in an individual standard sized galvanized battery cage equipped with drinkers and feeders. Rabbit does were fed a pellet diet containing the test ingredients, The diets were formulated (18.32% crude protein and 10.76 MJ kg^{-1} digestible energy) to meet the National Research Council recommendation for daily nutritional requirements for does. Five proven bucks were used to mate the does across the treatments. The twenty-five does were weighed prior to mating and at parturition for the litters and final weight at the end of the experiment. Kits were weaned at 6 weeks of age. The kits were weighed at birth and weekly till weaning. Feeds intake and refusals were weighed daily and samples were analysed for proximate components using the methods of AOAC[13]. Milk yield was estimated according to Lebas *et al.*[14]:

$$\text{Milk production of does} = (\text{Live weight of new born at 21 days of age-Live weight of new born})\times 1.18$$

Ethical approval: The study received the ethical approval of the Institutional Animal Care and Use Committee, through the Agricultural Biochemistry and Nutrition Unit of the Department of Animal Science, University of Ibadan, Nigeria.

Varieties of sweet potato studied: Two varieties of sweet potato plants CIP 440293 (Orange flesh) and TIS 87/0087 (White flesh) were harvested from the National Roots Crops Research Institute, Umudike, Abia State, Nigeria from May 2017 to September 2017. The harvested whole sweet potato roots were cleaned, chipped to about 2 mm thickness slices manually using a sharp knife and shade dried for 3-5 days with an average temperature of 32.9°C during the dry season. The leaves and vines were also shade dried for 3-5 days with an average temperature of 32.9°C during the dry season and they were thereafter milled to a fine powder and their chemical composition was determined.

The composite sweet potato meal contains 65% whole root and 35% of the leaves and vines[15] and fed at the graded levels. The diets were labelled as T1-control, 25 and 50% of orange flesh sweet potato composite meal were T2 and T3, respectively, 25 and 50% of white flesh sweet potato composite meal were T4 and T5, respectively. Other ingredients used include: -soybeans, maize offal, maize, rice offal, premix, bone meal and salt. The diets were formulated to meet 16% crude protein[15] (Table 1).

Sample preparation and extraction: Selected healthy roots from each variety were washed and cut into tiny parts using a knife afterwards thoroughly mixed for uniformity to attain samples weighing 400 g hence placed in a paper bag and dried to a constant weight in a hot air oven (DHG-9055A, Memmert Germany) set at around 105°C. For leaf samples, freshly developed leaf tips weighing about 200 g were washed, chopped into small pieces and oven dried at 70°C to achieve constant weight. The oven dried leaf and tuber samples were ground into a fine powder using an electronic mill (FW 100, Yusung Industrial Ltd, China). The powder was sieved using a 0.425 mm mesh size. The dry powder samples were then packed in airtight polyethylene bags and stored at 4°C for further analysis.

Crude protein determination: The Kjeldahl method was used to determine the Crude protein content[16]. A carefully weighed 0.5 g sample was digested with a known quantity of concentrated H_2SO_4 (Sigma-Aldrich, USA) in the Kjeltec digestion apparatus (Gerhardt vapodest, Germany). The digested material was distilled after being treated with alkali. The ammonia emissions were collected in a Kjeltec Automatic Distilling Unit with 4% boric acid. The ammonia generated by the digestion was retained in the boric acid, which was then titrated with 0.1N hydrochloric acid (HCl) (Sigma-Aldrich, USA). The protein content was calculated by multiplying the nitrogen concentration by a factor of 6.25.

Table 1: Gross composition of experimental diets fed to growing rabbits

		Levels of orange flesh CSPM		Levels of white flesh CSPM	
Ingredients	T1 (0%)	T2 (25%)	T3 (50%)	T5 (25%)	T6 (50%)
Maize	50.00	37.50	25.00	37.50	25.00
*CSPM	-	12.50	25.00	12.50	25.00
Soya bean meal	16.00	16.00	16.00	16.00	16.00
PKC	19.00	19.00	19.00	19.00	19.00
Fish meal	1.00	1.00	1.00	1.00	1.00
Wheat offal	8.50	8.50	8.50	8.50	8.50
CRM	2.00	2.00	2.00	2.00	2.00
Limestone	2.00	2.00	2.00	2.00	2.00
Bone meal	1.00	1.00	1.00	1.00	1.00
Vitamin-mineral premix	0.25	0.25	0.25	0.25	0.25
Table salt	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00
Calculated nutrients					
Crude protein	16.90	17.29	17.01	16.72	16.60
Crude fibre (%)	9.45	10.40	11.09	10.51	11.01
ME (kcal kg^{-1})	2788.00	2760.00	2690.00	2780.00	2680.00

*Each 1.5 kg of minerals, vitamins mixture contains manganese: 80 g, Zinc: 60 g, Iron: 30 g, Copper: 4 g, Iodine: 0.5 g, Selenium: 0.1 g and Cobalt: 0.1 g, Vitamin A: 12000000 IU, Vitamin D3: 3000000 IU, Vitamin E: 10000 mg, Vitamin K3: 2000 mg, Vitamin B1: 1000 mg, Vitamin B2: 5000 mg, Vitamin B6: 1500 mg, Vitamin B12: 10 mg, Biotin: 75 mg, Folic acid: 1000 mg, Nicotinic: 30000 mg and Pantothenic acid: 10000 mg, CSPM: Composite sweet potato meal, CRM: Cassava root meal, ME: Metabolizable energy, PKC: Palm kernel cake[10]

Determination of amino acid profile of sweet potato varieties: In this study, Amino acid profile was determined as described by Ayalew *et al.*[17] with modification. Amino acid analysis was carried out at the Evonik Nutrition and Care GmbH laboratory in Germany. Ninhydrin-Derivatized analysis using an amino acid analyser (Hitachi L-8800 Amino Acid Analyzer, Tokyo, Japan) was used to perform the test, which included performic acid oxidation and acid hydrolysis of amino acids.

The amino acids alanine, arginine, aspartic acid, cysteine, glutamic acid, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, proline and serine were determined using this approach. Norvaline was used as an internal benchmark to uniformly recover each amino acid from injection to injection. The method was calibrated across a range of 0.08-22.7% for each amino acid. Since acid hydrolysis entirely destroys tryptophan, a separate hydrolysis procedure is required for accurate measurement, hence tryptophan (Trp) was not studied[18].

Evaluation of protein quality: Based on the measured amino acid profiles, the nutritional value of the protein in the composite sweet potato meal was determined. The approach taken by Ayalew *et al.*[17] was used. The ratio of total essential amino acids (TEAA) to total amino acids (TAA) in the protein was estimated using the Chavan *et al.*[19] technique. The essential amino acid composition's amino acid score was computed using the method described by Chavan, *et al.*[19]:

$$\text{TEAA/TAA} = \frac{\text{Ile+Leu+Lys+Met+Cys+Phe+Tyr+Thr+Trp+Val+His}}{\text{Ala+Asp+Arg+Gly+Glu+His+Ile+Leu+Lys+Met+Cys+ Phe+Tyr+Pro+Ser+Thr+Trp+Val}}$$

Essential amino acid index (EAAI) was calculated according to Ijarotimi and Keshinro[20].

$$\text{EAAI} = \sqrt{[n\&(100a \times 100b \times \cdots 100j)/(av \times bv \cdots jv)]}$$

Where:

n is the number of essential amino acids, a, b ⋯. j represent the concentration of essential amino acids (histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine) in the tested sample and av, bv⋯. jv is the content of the same amino acids in standard protein (%) (egg or casein), respectively.

Predicted biological value (P-BV) was calculated according to Mune-Mune *et al.*[21]:

$$\text{P-BV} = 1.09 \times \text{EAAI} - 11.7$$

The predicted protein efficiency ratio (P-PER) was calculated by the regression equations as cited by Mune-Mune *et al.*[21]:

$$\text{P-PER} = -0.468 + 0.454(\text{LEU}) - 0.105(\text{TYR})$$

The nutritional index was calculated as cited by Ijarotimi and Keshinro[22]:

$$\text{Nutritional index (\%)} = \text{EAAI} \times \text{\% protein}/100$$

Statistical analysis: Data were analyzed using one-way analysis of variance (one-way ANOVA), followed by Duncan's multiple range tests using SAS 9.1 statistical package[23] (SAS, 2004). Differences among treatments were detected at a 5% level of significance.

RESULTS

Crude protein content and amino acid composition: The dry matter of the root and leaves of the two varieties of sweet potato ranged from 91.77 to 92.53% and were not significantly different from each other but were comparable to maize.

The amino acid profile of the two varieties of sweet potato is presented in Table 2. The methionine value was the highest ($p<0.05$) in maize (0.21g/100 g protein) followed by white flesh sweet potato (WFSP) leaves and vine, orange flesh sweet potato (OFSP) leaves and vine and OFSP root with 0.140, 0.135 and 0.107 g/100 g protein respectively with the WFSP root having the least value of 0.053 g/100 g protein. The value of cysteine and methionine followed a similar trend, with the maize having the highest value (0.230) and white flesh sweet potato having the least value (0.044). Combination of methionine and cysteine was absent in maize.

The amino acids profile of sweet potato leaf and vine showed that lysine (0.438-0.414 g/100 g protein) was the highest for WFSP and OFSP, respectively. Threonine value also followed a similar trend with the orange and white flesh sweet potato leave and vine having the highest value of 0.429 and 0.426 g/100 g protein respectively, values which were very close. Threonine value for maize was higher than the values of both varieties of the roots. The Arginine value in the white flesh, orange flesh sweet potato leaves and vine and that of maize were really close with values of 0.524, 0.500 and 0.485 g/100 g, respectively. Isoleucine value in maize is 0.385 and it is lower than that of WFSP and OFSP leaves and vine with values 0.418 and 0.418 g/100 g, respectively.

Table 2: Amino acid profile of the two varieties of sweet potato

Amino acid as in wet chemistry	OFSP root	OFSP leaf and vine	WFSP root	WFSP leaf and vine	Maize	p-value
Dry matter	92.350	91.770	92.130	92.530	89.710	0.1212
Crude protein	8.04^{b}	11.260^{a}	3.320^{c}	11.175^{a}	10.855^{a}	0.0001
Essential amino acid						
Histidine	0.11^{b}	0.141^{b}	0.053^{b}	0.148^{b}	0.330^{a}	0.0070
Isoleucine	0.24^{b}	0.42^{a}	0.12^{c}	0.42^{a}	0.39^{a}	0.0011
Leucine	0.42^{c}	0.71^{b}	0.21^{c}	0.72^{b}	1.34^{a}	0.0004
Lysine	0.21^{c}	0.41^{ab}	0.11^{c}	0.44^{a}	0.32^{b}	0.0019
Methionine	0.11^{ab}	0.14^{ab}	0.05^{b}	0.14^{ab}	0.21^{a}	0.0670
Phenylalanine	0.32^{b}	0.45^{a}	0.13^{c}	0.50^{a}	0.51^{a}	0.0015
Threonine	0.16^{b}	0.43^{a}	0.13^{b}	0.43^{a}	0.35^{ab}	0.0548
Valine	0.33^{b}	0.52^{a}	0.15^{c}	0.53^{a}	0.54^{a}	0.0008
TEAA	1.89	3.22	0.96	3.32	3.96	0.1345
Conditionally essential amino acid						
Arginine	0.33^{b}	0.50^{a}	0.13^{c}	0.52^{a}	0.49^{a}	0.0003
Methionine-cysteine	0.20^{b}	0.30^{a}	0.10^{c}	0.30^{a}	-	0.0001
Proline	0.23^{c}	0.43^{b}	0.12^{d}	0.42^{b}	0.95^{a}	0.0001
Glycine	0.31^{c}	0.52^{a}	0.14^{d}	0.52^{a}	0.41^{b}	0.0003
Cysteine	0.05^{b}	0.12^{b}	0.04^{b}	0.11^{b}	0.23^{a}	0.0094
TCEA	1.12	1.88	0.53	1.88	2.08	0.0102
Nonessential amino acid						
Serine	0.32^{b}	0.44^{a}	0.13^{c}	0.43^{a}	0.42^{ab}	0.0019
Alanine	0.33^{c}	0.53^{b}	0.15^{d}	0.53^{b}	0.81^{a}	0.0005
Aspartic acid	1.08^{a}	1.09^{a}	0.40^{b}	1.11^{a}	0.65^{b}	0.0029
Glutamic acid	0.73^{c}	1.04^{b}	0.34^{d}	1.05^{b}	1.98^{a}	0.0001
TNEAA	2.46	3.10	1.02	3.13	3.85	0.0054
TAA	18.35	23.72	7.70	23.86	29.22	0.0574

^{abc}Means with different superscripts on the same row are significantly different ($p<0.05$). **Orange flesh sweet potato (OFSP), White flesh sweet potato (WFSP), TEAA: Total essential amino acid, TCEA: Total conditionally essential amino acid, TNEAA: Total nonessential amino acid, TAA: Total amino acid

Valine and leucine value showed a similar trend, maize has the highest valine value (0.535), which is closely followed by the WFSP leave and vine, OFSP leave and vine and OFSP root with values of 0.528, 0.526 and 0.332, respectively with the WFSP root having the least value (0.145). Maize has the highest value (0.330) for histidine. The two varieties of sweet potato has a value ranging from 0.148-0.053. There was a similar trend for Phenylalanine, Glycine, Proline, Alanine and Glutamic acid with maize having the highest values followed by the leaves and vines of the two varieties and the root having the least.

The amino acid profile of the composite meal of two selected sweet potato varieties based on their protein content is presented in Table 3. The OFSP has the highest while the WFSP has the lowest amino acid profile. Methionine value observed in OFSP meal was 0.192 while WFSP meal has a value of 0.097. The Cysteine value in the OFSP meal was 0.164 while WFSP meal has a value of 0.092, actually follow a similar trend with that of the Methionine. The OFSP meal and WFSP meal has a value of 0.356 and 0.189, respectively. For Lysine, the composite OFSP meal has the highest value (0.462) while the composite WFSP has the lowest value (0.225). Threonine value was the highest (0.508) in the composite OFSP meal and composite WFSP meal has a value of 0.258 which were far apart. The Arginine value in the composite OFSP meal is 0.59 while the composite WFSP meal has the least value of 0.249. Isoleucine value in the composite OFSP meal is 0.488 which is relatively far apart from the value of composite WFSP meal (0.237). The composite OFSP meal has the highest Leucine value (0.834) while the composite WFSP meal has a value of 0.398. Valine and leucine followed a similar trend, composite OFSP meal has the highest valine value (0.664) while the composite WFSP meal has the lowest value (0.315). For histidine, composite OFSP meal has a value of 0.23 while the composite WFSP meal has a value of 0.102.

Protein quality: Table 4 shows the amino acid profiles of sweet potato composite meals. Sulphur amino acids (SAAs) (Met + Cys) were 0.36 g/100 g protein in orange-fleshed sweet potato composite meal and 0.19 g/100 g protein in white-fleshed sweet potato composite meal. The SAAs obtained were much lower than the WHO[24] mandated reference pattern (2.2–2.8 g/100 g protein or 22–28 mg g^{-1} protein).

The AAAs (Phe+Tyr) of the orange flesh sweet potato composite meal and white-fleshed sweet potato composite meal were 0.97 and 0.51 g/100 g protein, respectively. The percentage of essential to total amino acids (TEAA/TAA) was

Table 3: Amino acid profile of the two varieties composite sweet potato

Amino acid as is wet chemistry	Orange flesh CSP	White flesh CSP	Standard error
Dry matter	93.99±0.02	94.10±0.04	0.32
Crude protein	14.83±0.05[a]	6.13±0.02[b]	2.52
Essential amino acid			
Histidine	0.23±0.01	0.10±0.01	0.37
Isoleucine	0.49±0.08	0.24±0.01	0.07
Leucine	0.84±0.01	0.39±0.07	0.13
Lysine	0.47±0.04	0.23±0.01	0.07
Methionine	0.19±0.01	0.09±0.01	0.03
Phenylalanine	0.61±0.01	0.32±0.01	0.84
Threonine	0.51±0.01	0.26±0.01	0.72
Valine	0.67±0.01	0.32±0.01	0.10
TEAA	3.99±0.02	1.95±0.01	0.59
Conditionally essential amino acid			
Arginine	0.59±0.01	0.25±0.01	0.09
Methionine-cysteine	0.36±0.01	0.19±0.01	0.07
Proline	0.48±0.01	0.24±0.01	0.07
Glycine	0.58±0.01	0.28±0.01	0.09
Cysteine	0.16±0.01	0.09±0.57	0.19
TCEA	2.17±0.01	1.06±0.01	0.32
Nonessential amino acid			
Serine	0.52±0.01	0.28±0.01	0.07
Alanine	0.59±0.01	0.29±0.01	0.09
Aspartic acid	1.73±0.01	0.65±0.00	0.31
Glutamic acid	1.17±0.00	0.54±0.01	0.18
TNEAA	4.02±0.01	1.76±0.01	0.65
TAA	10.17±0.01	4.77±0.01	1.56

**OFSP: Orange flesh sweet potato, WFSP: White flesh sweet potato, TEAA: Total essential amino acid, TCEA: Total conditionally essential amino acid, TNEAA: Total nonessential amino acid, TAA: Total amino acid

Table 4: Protein quality of composite sweet potato meal based on their amino acid profile

Nutritional quality of amino acids	Orange flesh CSP	White flesh CSP	Standard error
TSAA(Meth+Cys) (g/100 g protein)	0.36±0.01[a]	0.19±0.00[b]	0.48
TArAA (Phe+Tyr) (g/100 g protein)	0.97±0.04[a]	0.51±0.02[b]	0.13
Leu/lleu ratio	1.71±0.06	1.67±0.07	0.01
TEAA/TAA (%)	39.16±0.06	40.86±0.01	0.49
TNEAA/TAA (%)	39.46±0.03	36.99±0.06	0.71
TEAA/TNEAA ratio	0.99±0.02	1.11±0.03	0.03
P-PER	1.04±0.04	0.85±0.02	0.06
EAAI (%)	18.89±0.05[a]	13.31±0.02[b]	1.61
P-BV	8.89±0.01[a]	2.81±0.01[b]	1.75
Nutritional index (%)	2.79±0.03[a]	0.82±0.00[b]	0.57

Mean±SD, TArAA: Total aromatic amino acids, TSAA: Total sulfur amino acids, TEAA: Total essential amino acids, TNEAA: Total nonessential amino acids, TAA: Total amino acids, His: Histidine, Arg: Arginine, Leu: Leucine, Ile: Isoleucyne, PER: Protein efficiency ratio, EAAI: Essential amino acid index, BV: Biological value. Title of figure should be below the figure

39.16% for orange-fleshed sweet potato composite meal and 40.86% for white-fleshed sweet potato composite meal. The average predicted protein efficiency ratios (P-PER) for orange-fleshed sweet potato composite was 1.04 and for white-fleshed sweet-potato composite was 0.85.

Reproductive performance of the rabbit doe fed graded levels of two varieties of sweet potato composite meal: The inclusion effect of two varieties of sweet potato composite meal based diets on growth performance of doe is presented in Table 5. The gestation length of does fed on T4 was higher (32.40 days) than those of the other dietary treatments though the difference was non-significant (p>0.05), whereas, T1 (0% of either of the two varieties of the composite meal) has the least gestation length (31.40 days).

Weight gain of doe during the entire period of gestation did not differ significantly (p>0.05) from each other. However, significant (p<0.05) difference was observed in the weight of doe at parturition. The T1 (2707.0) and T2 (2640.0) did not differ significantly (p>0.05) from one another. However, T1 (2707.0) and T2 (2640.0) had the highest values followed by T4 (2384.0 g), T3 (2294.4) and T5 (2214.2 g). Average weight gain of the doe and feed conversion ratio during the gestation period were not affected by the dietary treatments.

Table 5: Reproductive performance of rabbit does fed graded levels of two varieties of sweet potato composite meal based diets

		Levels of OFCSP		Levels of WFCSP			
Parameters	T1 (0%)	T2 (25%)	T3 (50%)	T4 (25%)	T5 (50%)	SEM	p-value
Gestation period							
Feed intake/day (g)	103.45	97.95	99.65	103.20	103.75	1.18	0.2808
Body wt at service (g)	2408.8	2223.2	2094.8	2041.8	2080.4	109.34	0.0014
Body wt of doe at parturition (g)	2707.0[a]	2640.0[a]	2294.4[bc]	2384.0[b]	2214.2[c]	109.78	0.0002
Body wt of doe after weaning of the kits (g)	2363.8	2865.2	2482.8	2597.4	2282.0	101.87	0.6216
FCR during gestation	2.13	1.78	1.27	1.62	2.36	0.19	0.4926
Mean doe wt gain/week	74.55	104.20	99.90	85.55	76.95	5.97	0.2658
Survival rate (%)	100	100	100	100	100	0.00	0.000
Post-gestation period							
Post gestation average feed intake (g)	121.23[ab]	116.40[b]	124.03[ab]	126.93[a]	128.37[a]	8.34	0.0544
Post-gestation average doe weight gain/week	270.8	297.0	306.2	310.4	293.6	21.49	0.5891
Doe wt gain/week (g)	87.50	79.40	61.24	62.08	58.72	5.75	0.589
Post gestation FCR	2.37	2.17	3.19	3.53	4.14	0.37	0.460
Total milk yield (g)	2137.01	2124.68	2120.47	2119.52	2112.73	0.004	0.598
Survival rate (%)	100	100	100	100	100	0.00	0.000
Sex ratio of kits at weaning of rabbit doe fed two varieties of sweet potato composite meal at graded level							
Total number of kits at birth	20	24	14	25	25	0.00	0.00
Total number of kits at weaning	12	13	14	15	13	0.00	0.00
Ratio of male to female at weaning							
No of males	6	7	6	8	6	0.00	0.00
No of females	6	6	8	7	7	0.00	0.00
Sex ratio	1.00	1.67	0.75	1.14	0.86	0.00	0.00

[a-c]Means with different superscripts on the same row significantly differs ($p<0.05$) from one another, **OFCSP: Orange flesh composite sweet potato meal, WFCSP: White flesh composite sweet potato meal

Table 6: Growth performance of kids of rabbit doe fed graded levels of two varieties of sweet potato composite meal

		Levels of OFCSPM		Levels of WFCSPM			
Parameters	T1(0%)	T2(25%)	T3(50%)	T4(25%)	T5(50%)	SEM	p-value
Gestation length (days)	31.40	31.80	32.00	32.40	31.80	0.16	0.78
Litter size at birth (Nos)	4.80	4.00	4.80	5.00	5.00	0.19	0.94
Litter size at 3 weeks (Nos)	3.00	2.40	4.80	3.20	3.20	0.15	0.69
Litter size at (6 weeks) weaning (Nos)	2.60	2.20	4.80	3.00	2.60	0.13	0.70
Survival rate (%)	70.24	45.90	63.57	61.24	52.00	4.31	0.48
Litter wt at birth (g)	35.31	32.47	33.26	29.44	34.52	1.02	0.79
Litter wt at 3 weeks (g)	264.03	254.13	252.13	251.45	246.57	10.29	0.47
Litter wt at (6 weeks) weaning (g)	569.94	540.1	553.00	552.82	527.97	23.16	0.41
Av wt gain/kid/week (g)	89.10	78.45	86.62	86.72	82.24	3.71	0.37

OFCSPM: Orange flesh composite sweet potato meal, WFCSPM: White flesh composite sweet potato meal[7]

No significant ($p>0.05$) variation was observed in the studied parameters during the post-gestation period except for the average feed intake. T5 and T4 had the highest feed intake values (128.37 and 126.93 g) that are similar ($p>0.05$). They were followed by T1 (121.23 g), T3 (124.03) and T2 (116.40 g).

Table 5 shows the sex ratio of kits fed two varieties of sweet potato composite meal based diets. The T5 and T4 had 25 kits at birth followed by T1 and T3 with 24 kits at birth and T2 with 20 kits at birth. At sixth week (weaning), T4 had 15 kits, followed by T3 with 14 kits while T1 and T5 with 13 kits. The T2 had 12 kits.

Growth performance of kids at weaning is presented in Table 6. The feed offered across the treatment groups did not significantly ($p>0.05$) affects all the reproductive parameters examined at 3 and 6 weeks. Litter weight at birth, at 3 and 6 weeks (weaning) and average weight gain per kid per week were not significantly influenced by the dietary treatments.

DISCUSSION

Crude protein content: The crude protein values of vines obtained in the study agree with the findings of Tesfaye *et al.*[25], who reported similar values for unspecified sweet potato variety. The crude protein value recorded in the selected two varieties of sweet potato roots were however slightly lower than those reported for maize i.e orange flesh sweet potato root (8.08%) and white flesh sweet potato root (5.30%) but were higher than those reported by Ukom *et al.*[26] which ranged from 3.28-4.16%. Sanoussi *et al.*[27] reported similar values which ranged from 2.03-4.19%. The variation in protein content reflects the genetic diversity of the sweet potato genetic pool as the varieties used in this study were grown under similar environmental conditions. The results obtained for the sweet potato root in this study agree with Oloo *et al.*[11] who reported that the sweet potato root usually have higher protein content than other roots and tubers, such as cassava and yams. However, according to the results of the present study, crude protein contents observed in the leaves and vines were higher than that of maize. The values were in the range of 11.35-11.52% but lower (17%) than those of Hang[28] but higher (6.34%) than those reported by Akinmutimi and Osuagwu[29]. This finding suggests that sweet potato leaves contain more protein than the root. As a result, sweet potato leaves can be a rich source of protein, a previous study reported that any plant foods that can supply around 12% of their calorific content from protein are good sources of protein[30].

Amino acid composition: Amino acids are the building blocks of proteins, the nutritional quality of a protein is determined by the amount, proportion and availability of its amino acids. The amino acid contents recorded in the two cultivars of sweet potato is similar to earlier research on plant-based protein that found a significant quantity of Glumatic acid[22]. The most abundant amino acids was detected in sweet potato root (aspartic acid and glutamic acid), Montagnac *et al.*[31] found similar results for Dioscorea species and cassava tubers. The amino acids with the highest concentration were found in leaves (aspartic acid and glutamic acid), this result is consistent with a previous study conducted by Akubugwo *et al.*[32] who reported the highest concentration for *Amaranths hybridus* leaves.

Methionine with the lowest concentration was observed in both the root and leaf parts, which is consistent with the findings of Van Hal's[33] on sweet potato cultivar germplasm accessions. These findings are comparable to the majority of vegetable protein sources[21] except for tryptophan, which was not detected in this study, sweet potato tuber and leaf contained all of the necessary amino acids. Methionine and histidine were identified in little amounts in the root and leaf parts, which might be explained by one of two factors: They may have been denatured during analysis or their values in sweet potato are extremely low. This result is consistent with Montagnac *et al.*[31] who reported the poor availability of Methionine.

These findings showed that sweet potato may be used to boost protein quality by using necessary amino acids contained in sufficient amounts in either of its edible parts, particularly when looking for a high-quality protein for animal diets. Essential amino acids are present in proportions that correspond to the demands of animals in a balanced or high-quality protein.

For the composite sweet potato meal, there was a similar trend for phenylalanine, glycine, proline, alanine, serine, aspartic acid and glutamic acid with the composite OFSP meal has the highest and the composite WFSP meal has the lowest value. Although, the contents of the crude protein in composite sweet potato meal are high and the amino acid profile of the composite sweet potato meal shows comparable improvement from the individual sweet root or leaves and vines.

There is lack of study on the protein levels and nutritional value of composite sweet potato meal in terms of amino acids. Except for tryptophan, which was not measured in this study, all of the essential amino acids were present in appreciable amounts in the composite sweet potato meal, which follows a similar trend as the tuber and leaf of sweet potato. Methionine and histidine were also found in limited quantity in the composite meal. Thus, composite sweet potato meal could be a potential major ingredient in livestock diet.

Protein quality: Dietary protein has a strong influence on reproduction. Good quality protein may boost the availability of amino acids (AA) for intestinal absorption and their glucogenic potential[34]. It may also contribute to the provision of an important amino acid like methionine, which might improve fertility in the animals[35]. Results obtained in this investigation indicated that rabbit does fed the composite sweet potato exhibited superior reproductive performance, with improved fertility and pregnancy outcomes (litter sizes, birth weights and weaning weights) compared to those fed on diet without sweet potato composite meal. Protein quality had a beneficial influence on the energy status of rabbit does and improve its reproductive performance. Protein quality particular amino acid composition may have beneficial effects on body weight and metabolism. Rodríguez *et al.*[36] reported that amino acid-rich meals increased rabbit fertility and pregnancy outcomes.

In the early days of lactation, growing foetuses and kids are completely reliant on their dams for the nutrients they require for growth and development. Balanced diet increases oocyte quality, embryo growth and implantation throughout the early stages of pregnancy by delivering certain amino acid and/or energy sources. Furthermore, most foetal lipids are transferred from maternal circulation through the placenta during the later stages of pregnancy and are derived from the food or fat lipolysis[37], producing the fat deposits for kit's survival. In the present study, reduction in the body weight of dams was not observed.

Amino acids are utilised for membrane phospholipid production, therefore they are vital for rabbit kit growth and development. Other non-essential amino acids are needed to improve immunological function and overall health.

Reproductive performance of doe fed graded levels of two varieties of sweet potato composite meal: This data revealed that the composite sweet potato diet could help boost metabolism throughout pregnancy, supplying the dietary needs for foetuses while not depleting the dams' energy reserves. Because rabbit kits are altricial, the better pregnancy outcomes might potentially be attributed to enhanced litter development and viability[38]. The dietary concentrations of several Amino acids are crucial for litter development and health, as well as colostrum immunoglobulin content, milk output and composition[38].

The mobilization of body reserve to synthesize milk for kits could be attributed to the consistently same weight observed during the lactating phase. Across all the treatments, average feed consumption ratio was positive and proportional throughout the gestation phase. Values of the average feed consumption ratio were consistent with those reported by Iyegbe-Erakpotobor[39] for grower rabbits.

Across the different treatments no significant difference was observed in the gestation lengths. This observation was in line with the reports of Iyegbe-Erakpotobor[39]. There were no abortions or stillbirths observed during the study.

The use of composite sweet potato meal for reproductive rabbit does proved to be sustainable alternative, although overall reproductive performance was slightly affected when place side by side with the conventional diets, However, they provided opportunity of savings for the farmers. The findings of the present study is consistent with a previous study conducted by Machado *et al*.[40] who evaluated simplified diets containing cassava byproducts based on hay from the upper third of *cacau*-variety cassava foliage and alfalfa hay for does rabbits. Machado *et al*.[40] reported a depletion in the performance of does and growing rabbits after receiving cassava foliage hay. Machado *et al*.[40] emphasized on further research on cultivars with improved nutritional values.

The doe rabbit increases the rate of feeding to compensate for milk production in order to satisfy young rabbits for growth and development, as they make better use of fibrous feeds for growth and development.

CONCLUSION

In terms of crude protein and amino acid quantity, as well as protein quality, the sweet potato leaf sample outperformed the root sample. Sweet potato composite can be used to complement standard protein sources for livestock by providing necessary amino acids (Leu, Ile, Thr, Sulfur Amino Acids (SAAs) and Aromatic Amino Acids (AAAs) in enough amounts in either of its edible parts. In both root and leaf samples, the amino acid content varies between the two varieties. In the current study, the sweet potato composite meal provided an adequate quantity of protein and functional amino acids for the optimum completion of specific physiological processes related to milk production and reproduction. These advantages were demonstrated by rabbit does' improved metabolism, immunological state, milk production and reproductive success at various reproductive stages. Composite sweet potato meal of the two varieties can be utilized to compensate for poor quality and protein deficiency. The composite mix is adequately comparable to maize and has a potential to be used up to 50% replacement for maize in the life cycle feeding of rabbits. Moreover, modification in the mix can be made to optimise protein supply and quality.

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